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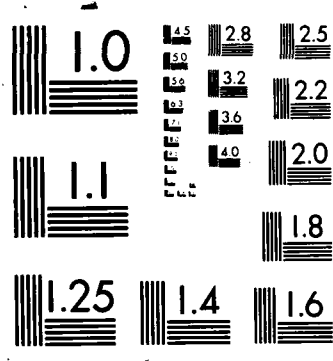
High Density Digital Data Recording System

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January 28, 1987

Scientific Report No. 3

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"This Technical Report has been reviewed and is approved for publication"

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFGL-TR-87-0044	2. GOVT ACCESSION NO. AD-A181 115	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) High Density Digital Data Recording System		5. TYPE OF REPORT & PERIOD COVERED Scientific Report No. 3
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jack Allison and Thomas Bertenshaw		8. CONTRACT OR GRANT NUMBER(s) F19628-85-C-0006
9. PERFORMING ORGANIZATION NAME AND ADDRESS Electronics Laboratory - CEAT Oklahoma State University Stillwater, Oklahoma 74078-0116		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62101F 765904BL
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory Hanscom Air Force Base, Mass 01731 Contract Manager: Kenneth Walker/LCT		12. REPORT DATE 28 January 1987
		13. NUMBER OF PAGES 46
14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)		15. SECURITY CLASS. (of this report) unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

High Density Digital Data Recording, Laser Recording, WORM, Laser disc, archiving

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The state-of-the-art in High Density Digital Data Recording is such that it is now possible to evaluate the capabilities of write-once-read-many (WORM) laser disc systems vis-a-vis magnetic tape spooling. Most of such a systems' components can be purchased off-the-shelf. The potential to store unalterable data, in vast amounts, in a small space, or a medium impervious to time degradation can be realized with current technology.

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SUMMARY:

The state of the art in recording technology is shifting from magnetic media systems to those which both write and read to a media by coherent light systems, i.e. a laser. The anticipated advantages of a laser system over magnetic systems include gigabyte storage through a system weighing fractions of the corresponding tape system; potential throughput speeds several times those of magnetic systems; capture of unalterable data; a virtually unlimited storage lifetime; essentially unlimited read cycling without data lass; a manyfold reduction in physical data storage media, coupled with a simultaneous manyfold increase in data volume stored.

The time threshold for assembling and evaluating a laser system capable of replacing tape mass transport systems for archiving data, and real time data capture in the field is here. Commercial systems possessing the potential to be converted to those uses are presently available. With that in mind, a prototype system conceived to accomplish those ends is proposed herein.

BACKGROUND:

The present system in use for both recording and archiving test data is by magnetic tape recording. The current system generally employs a high speed, high bandwidth, multiple track tape streamer to record both digital and analog data in real time. The real time copy also serves as the archive copy, and obviously, duplicates can be made as required.

There exist some inherent hazards with the present system. The recording media is subject to inadvertent degaussing which destroys all recorded data. The media is also subject to abrasive wear during playback, which degrades fidelity and introduces noise, both of which threaten low level analog data. The abrasive wear factor is also hazardous to high bit rate digital data. Further, the inherent shelf life of the recording media is not unlimited. As a practical matter, shelf life is proportional to handling care, mechanical condition of the tape transport/record head combination, ambient magnetic environment, ambient environmental conditions such as temperature, humidity, atmospheric corrosive constituents, etc. In short, the storage life may range from a few years (two or three) to greater than thirty, depending upon the vagaries of hazard the recording media is subjected to.

Magnetic spooling recording, such as tape recording, also possesses some restrictive physical limitations with regard to recording duration. In general, a requirement to record higher frequencies dictates a corresponding higher transport speed to faithfully capture the data. As a consequence, the amount of

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tape required to record a given amount of data for a specified
recording duration increases proportional to transport speed
requirements. Currently, to record the data from a fifteen
minute flight at 120 inches-per-second transport speed, requires
approximately six pounds of tape mounted on a fourteen inch
reel. This current combination has a theoretical capacity of
storing 230 megabytes per track, assuming a 2 megabit data rate.
The recording machine necessary to accommodate this combination
is fairly large and massive. The models locally in use weigh
approximately one hundred pounds and occupy somewhat more than
three cubic feet of volume. A change in recording requirements
which impose longer durations or higher data capture rates would
also impose larger tape transport and tape mass requirements.
These relationships are not imposed by the electronic
components, but rather by the mechanical constituents required
to mount and transport a heavy mass at a high speed.
The above limitations, notwithstanding, have served admirably
well in the past to meet the requirements of recording and
preserving large amounts of data, both in the field and for
archive purposes. Given a reasonable amount of care, quality
reproductions of real time data have been captured, stored, and
preserved for many years. There is however, an emerging
technology, currently available from manufacturing sources which
has promise of being able to match or exceed tape transport
systems as a method of recording and archiving data. This newer
technology employs a process of recording digitized information
on a media by means of writing and reading using a coherent

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light source. These devices are commonly or collectively known as laser discs. Manufacturers claims for the available systems vary widely, as do the protocols of accomplishing the task. While the diversity of approach is as great as the number of candidates in the field, the prospect that the concept of real time recording and archiving using optical methods is believed to be achievable now.

There are several reasons for considering an undertaking to evaluate the merits of laser disc technology as a supplement for, or an eventual replacement for, tape transport mechanisms. Two of these advantages is size and data capacity. Current off-the-shelf technology is available in 5.25 and 12 inch diameter discs, which weigh but a few ounces. The data storage on the devices range from 400 to over 2500 megabytes of data. The smaller of these two units is physically able to be mounted in, and operate from a computer similar to an IBM portable PC, (Personal Computer - a trade name for a type of micro computer) or any other comparable portable PC. The larger 12 inch device is equally capable of interfacing with micro computers of this kind, but it is peripheral to the CPU chassis. The data transfer rate of these devices exceed the current tape system from 10 to over 150%.

An added benefit inherent in the current technology is that the recording media allows itself to be written to only once. While information can be written one time, it nevertheless can be read an indefinite number of times. The built-in advantage to this system is that it provides an unalterable audit trail, in which

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an analyst is guaranteed a faithful reproduction of the original data. Errors caused by inadvertent write-over of data are precluded with this type of (known as WORM, Write Once Read Many) laser disc technology.

The significant disadvantage in the off-the-shelf technology available today is that the laser disc recording devices provide for only a single track of data per disc at a time. The immediate impact of this constraint is that simultaneous, or parallel, data cannot be captured in time coincidence. There are possibly some "work arounds" to this limitation which might largely negate the disadvantage of serial string recording of time coincident data. However any such scheme would require developmental testing.

A project is proposed in which the merits of optical recording versus magnetic tape recording are investigated using WORM devices and their host microprocessor. Two goals of the project are proposed:

 a. the development of an ensemble capable of archiving unalterable data.

 b. the development of an ensemble capable of capturing unalterable data in the field.

Supporting these goals are several objectives, which include:

 1. the development and testing of a workable scheme which negates the loss of simultaneity in recording time coincident data.

 2. the assembly of, and field testing of at least one equipment ensemble capable of satisfying goal a.

 3. the assembly of, and field testing of at least one equipment ensemble capable of satisfying goal b.

 4. determining the feasibility and/or advisability of using only one type of equipment ensemble to satisfy both goal a. and goal b.

 5. maximizing data capture rates to the limit of the capacity of currently available equipment.

 6. increasing the data storage capacity per unit of storage medium to the limit of currently available equipment (unit of storage medium is currently 9600 feet of one-half inch magnetic tape; a unit of storage with optical technology is the appropriate optically read disc).
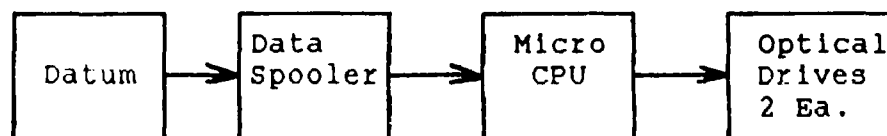
 7. developing techniques to restore simultaneity in

displaying time coincident data.

8. develop an ensemble package using commercially
available off-the-shelf equipment, with a minimum of custom
design.

Two configurations, each with a unique recording constituent roster, are proposed for evaluation. Both configurations, however, would be hosted by a micro computer similar to an IBM AT PC or equivalent. Therefore the differences in configuration devolves into the type of optical disc system with the interfacing appropriate to the particular system. The systems chosen for evaluation are representative of the range of capacity currently available from the optical disc industry. One system is very small and lightweight, and can be virtually contained within a portable micro-processor chassis, with a minimum of one five pound peripheral. The other system, while hosted by the same computer type cannot be self contained; this larger system requires some seventy pounds of peripherals. The major capability difference between the two systems is data storage capacity. In the case of the smaller system, the storage capacity exceeding 200 megabytes per disc surface, while the larger has a capacity exceeding 1300 megabytes per surface. Both systems have the capability of double sided writing, which effectively doubles those numbers for data storage per storage unit.

A representative block diagram for the smaller system (System 1) is:

```
┌─────────┐     ┌─────────┐     ┌─────────┐     ┌─────────┐
│         │     │ Data    │     │ Micro   │     │ Optical │
│ Datum   │ ──▶ │ Spooler │ ──▶ │ CPU     │ ──▶ │ Drives  │
│         │     │         │     │         │     │ 2 Ea.   │
└─────────┘     └─────────┘     └─────────┘     └─────────┘
```

A representative block diagram for the larger system (System 2) is:

```
┌─────────┐      ┌─────────┐     ┌─────────┐     ┌─────────────┐     ┌─────────┐
│ Datum   │ ───► │ Data    │ ──► │ Micro   │ ──► │ Formatter   │ ──► │ Optical │
│         │      │ Spooler │     │ CPU     │     │ Controller  │     │ Drive   │
└─────────┘      └─────────┘     └─────────┘     └─────────────┘     └─────────┘
```

A signal flow diagram of each system follows (recognize that the micro-processor CPU and spooler are physically the same units for both systems):

```
            System 1                      System 2

            Datum                         Datum
              |                             |
            Spooler                       Spooler
              |                             |
         ┌─ CPU                        ┌─ CPU
         |                             |
         └─ Interface ─┐              └─ Interface ──────────────┐
                       |                                         |
            Disc Drive ─┤             ┌─ Formatter/Controller ──┘
                        |             |
            Disc Drive ─┘             └─ Disc  Drive
```
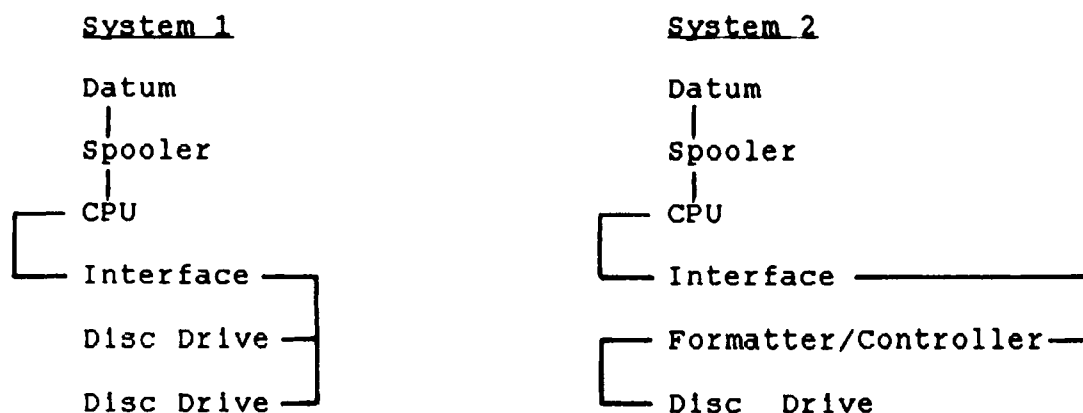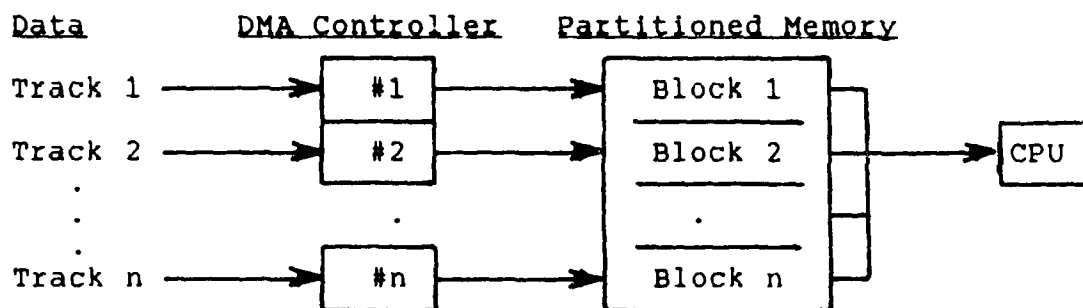
Initially System 1 will be evaluated for its ability to perform in the field, and System 2 for its ability to archive. However, either system may ultimately prove capable of performing both functions. This proposed evaluation will investigate and determine the relative strengths and weakness of each system as each is configured to support both goal a. and goal b. This type of "fly-off" will then be gauged against the merits of the currently used magnetic tape system as the benchmark.

The precise configuration of the Data Spooler has not as yet been fixed. This system component will perform the task of interleaving time coincident parallel datum into serial data for transcription onto the optical media. Presently a scheme is under consideration which DMA's (Direct Memory Access) a specific track of data into an assigned block of memory, each block under the control of its own DMA controller. Each block acting as a high speed FIFO (First In First Out) buffer for serial retrieval and subsequent transcription under CPU control.

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The necessary protocol, along with minimum track/memory
requirements are an expected deliverable result of this proposed
evaluation. Every attempt will be made to use commercially
available off-the-shelf modules as a spooler; failing that a
custom designed spooler will be built using the highest speed
MOS technology obtainable. The block diagram of such a
sub-system would be similar to:

<u>Data</u>   <u>DMA Controller</u>   <u>Partitioned Memory</u>

```
Track 1 ──────────▶ ┌─────┐  ──────▶  ┌───────────┐┐
                    │ #1  │           │  Block 1  ││
                    └─────┘           ├───────────┤│
Track 2 ──────────▶ ┌─────┐  ──────▶  │  Block 2  ││ ──────▶ ┌─────┐
    .               │ #2  │           ├───────────┤│         │ CPU │
    .               └─────┘           │     .     ││         └─────┘
    .                   .             ├───────────┤│
Track n ──────────▶ ┌─────┐  ──────▶  │  Block n  ││
                    │ #n  │           └───────────┘┘
                    └─────┘
```

There are intricate timing relationships to be accounted for
between data cycle time and spooler clock cycles to prevent loss
of data caused by a read/write conflict for the bus.
Ultimately, the relationship between time needed to write data
and the time needed to transfer data to the CPU will dictate the
maximum number of tracks which can be accommodated. At least
two different schemes are in consideration, however neither is
at a sufficient degree of maturity at this point to determine
which is the most meritorious. Again, the protocol selected,
developed, and tested during the evaluation will become part of
the deliverable system.

The commercially available equipment proposed for this evaluation includes the following:

System 1	System 2
IBM PC AT or equivalent	System 1 micro-computer
Optotech PC controller	Optotech SCSI Controller
Optotech #5984 Disc Drive	Hitachi OF301 Formatter
	Hitachi OD301A Disc Drive

Selection of the Data Spooler has been deferred pending the results of an industry search to determine whether or not such a device is available off-the-shelf, or must be custom made. The cogent performance characteristics of the WORM disc systems for the two configurations are:

	System 1	System 2
Disc transfer rate (bps):	2.2 Meg	3.52 Meg
Formatter transfer rate (Bps):	NA	1.5 Meg
Capacity per disc side (Bytes):	202 Meg	1310 Meg
Capacity per disc (Bytes):	404 Meg	2620 Meg

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The estimated hardware costs are as follows:

IBM PC AT or equivalent	$5000
Data Spooler	3000

System 1

PC Controller	650
Disc Drives (2 each)	9400
Discs (10 each)	2500

System 2

SCSI Interface	650
Formatter/Controller	4200
Disc Drive	11300
Discs (5 each)	2250
Miscellaneous	
Cables/Connectors	200
Electronic Components	500
Bits and pieces	500
Grand Total (Hardware):	$40150

It is anticipated that twelve man-months of effort will be required to design, fabricate, and evaluate a system of this kind. The design effort includes the generation of required software. The time line can be reduced to seven man-months if a suitable commercially available spooler is found. In either event, operationally ready hardware will be delivered at the end of the applicable time line.

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APPENDIX A

The following pages are a brief tutorial on laser disc
technology, which is the result of an engineering study done by
a staff member of Oklahoma State University's Electronics Lab.
The study is perishable in the sense that this whole field of
technology is in its embryonic phase, and standards have not
been frozen in place. Further, active industrial research is
ongoing to the extent that more than one approach has promise;
hence it is difficult to foresee with certainty what the
preferred methods/systems will be within five years. All that
notwithstanding, WORM technology, for all its present
limitations seems to be the right choice for both archiving and
non-alterable data capture. Therefore the following document is
included within this proposal for background purposes.

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PRESENT STATUS-AND FUTURE POSSIBILITIES
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PRESENT STATUS- AND FUTURE POSSIBLILITIES FOR
READ-WRITE OPTICAL STORAGE SYSTEMS

1.0   INTRODUCTION

1.1. Recent advances in laser technology have led to the development of laser based data storage systems that offer significant advantages over conventional storage systems based on magnetic tapes or disks. This Report will examine the characteristics of these laser optic storage systems, describe some of the research efforts underway to perfect and standardize their performance, and explore the potential advantages and problems associated with their use in large data storage systems.

Read-write systems have been under development in laboratories in Europe, America, and Japan for the past five years. Some systems have reached beyond the development stage to prototype units with significant performance capabilities. (One technology promises several million read-write cycles in the near future.) Several non-compatiable technologies are under development, and no industry standard seems likely in the next two or three years.

1.2. The use of optical techniques and materials for data storage has several advantages over conventional magnetic storage techniques [1,2,3]. An optical storage system provides higher density of stored material as well as a means for data recording (approximately 3×10^8 bits/inch^2 for magnetic storage and 13×10^8 bits/inch^2 for laser storage) and retrieval without physical contact with the medium. Remote read/write operations have significant advantages over conventional physical operations in terms of overall system reliability, maintenance, and wear on the recording machine. Typical magnetic read/write heads must either contact, or be within a few tenths of a micron of the tape or disk surface. Optical heads can operate effectively from a distance of a few millimeters from the medium, reducing the need for precise vertical alignment and highly controlled environments.

In an optical storage system, the recording medium is generally embedded in a disk that rotates beneath a focused laser beam. The laser and its associated optics and optoelectronics constitute a read/write head that can move radially to address different tracks on the disk. Read only disks consist of a plastic substrate on which the information is prerecorded in the form of surface moldings. Write once and erasable disks utilize an appropriate substrate on which the recording medium is deposited in a thin film form. Ablative media with tellurium layers and bubble-forming media with gold-chromium layers are used in most of the write-once systems, while magneto-optic and phase-change media are in the erasable group.[2,4,5,6].

2.0 WRITE ONCE OPTICAL STORAGE SYSTEM

2.1 In write once optical systems, data is stored optically by writing on light-sensitive material with pulses from a tightly focused laser beam. The laser pulse produces a visible change in the impact area, typically a pit, blister, or darkened spot that reflects more (or less) light than the surrounding area. The recorded data can be read by scanning the surface with a continuous laser beam that is weak enough to have no effect on the storage medium. One milliwatt of laser power is more than sufficient to perform the read function, and ten milliwatts is sufficient to write to some of the systems under development. Such power requirements clearly indicate that small, compact, and portable systems are entirely feasible.

The disk drive is the system component that writes data to and reads data from the optical disk. Within the electro-optics area of the disk drive is the laser and the optics required for writing, reading, focusing, and playback tracking. A translation slide is usually used to support and move the optical head, read/write, and focus optics, while a servo-controlled spindle rotates the disk at a precise speed for the read or write operations. The disk drive electronics includes the servo electronics that control all of

the disk drive moving mechanisms and channel electronics that transfer data to and from the media.

2.2   The basic components of an optical reading head are shown in Figure One.[7] As shown in Figure One, part of the laser beam is deviated by means of a small wedge. This beam is incident on the disk at a specfic angle that causes the distance between the side spot and the main spot to increase as the disk goes up. The position of the side spot is measured in the image plane of the disk (in the light source plane) by means of a split photodiode. For convenience, a second wedge is placed in the returning skew beam, increasing the distance between the laser and the photodetetector. In this way a servo system with a large acquisition range is obtained.[7]

2.3.   The read/write portion of a laser disk system contains a single read/write station where the data is stored and retrieved from the disk. The media disk is mounted on a spindle mechanism where it is rotated at a constant angular velocity within its protective enclosure. Highly accurate servo control systems within the read/write unit precisely control the focusing, tracking, and slide the spindle actuation functions of the unit. Data handling is performed by channel electronics that include laser modulation, playback direction, and data reconstruction. the write function is done one track at a time, but recent advances in handling capacity facilitate multiple track playback that effectively increases output data rate and search speed.

DISK

N = 0.58

CYLINDRICAL
LENS

N = 0.29

DIODE LASER

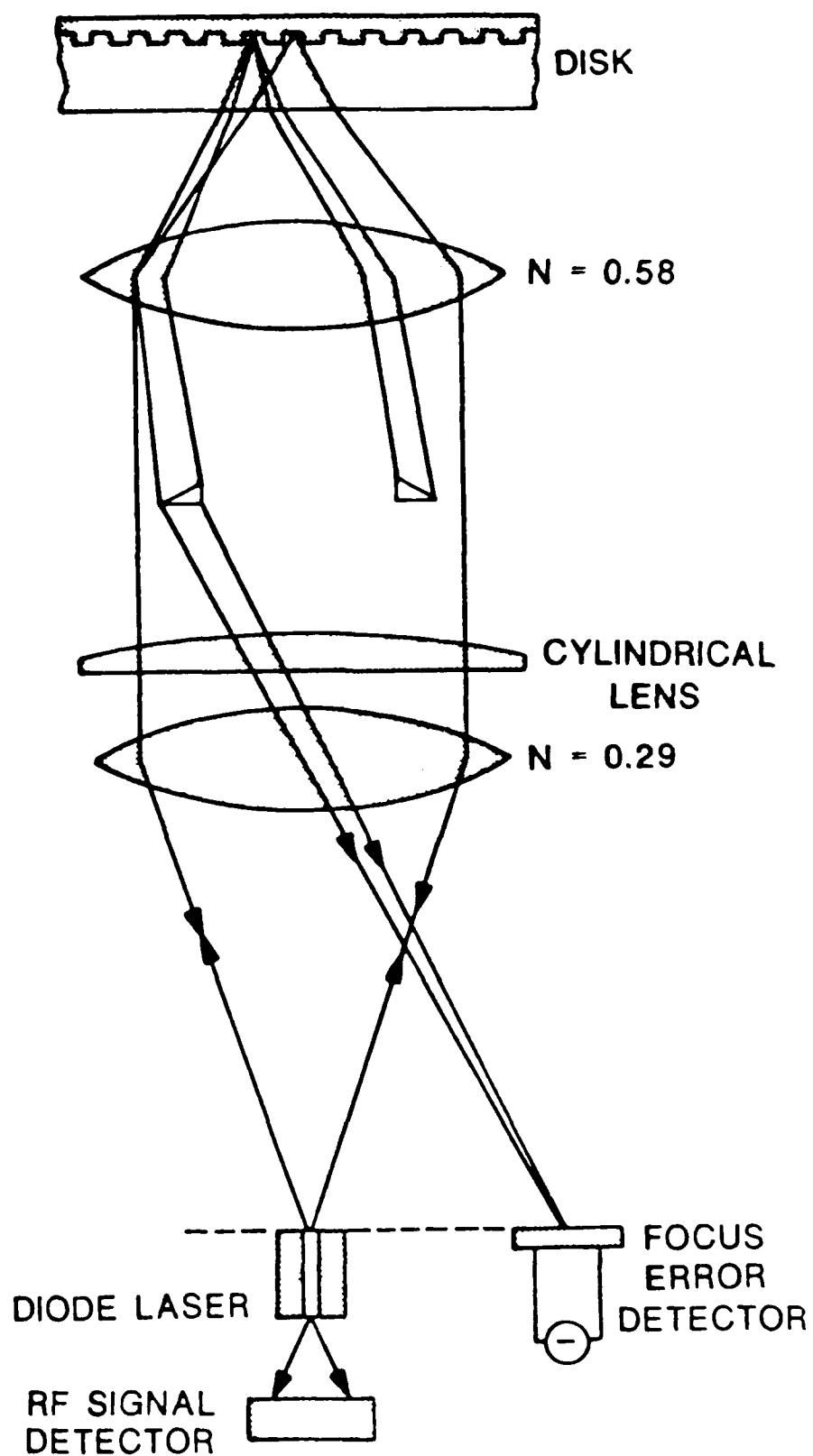FOCUS
ERROR
DETECTOR

RF SIGNAL
DETECTOR

FIGURE ONE. Basic Components of an Optical Reading Head

2.4 Write once optical disk systems are available commercially. Some utilize 30cm (12 inch) disks with a double-sided capacity of 2 GBytes, a corrected residual error rate of 10^{-12}, and a data transfer rate of 3.83 Mbits/sec.

3.0. ERROR MANAGEMENT AND CORRECTION

3.1 A variety of error control measures are taken to insure the integrity of the data stored in most optical disk systems. The first of these control measures deals with the defects that occur when the disks are manufactured to provide a low raw bit error rate. Second, a protective covering consisting of an overcoat and a dust free enclosure is used to keep unwanted particles from affecting data during record and playback operations. The overcoat and enclosure also protect the disk from damage due to handling.

3.2 Commerically available write once systems have a bit-error specification of 10^{-12} for data retrieval. Figure Two indicates the type of error correction scheme generally used to obtain such a specification. Data is encoded before writing, and redundant bits are added that can be used to correct short bit-error bursts. Interleaving the encoded data on the disk futher improves error correction by spreading the effect of a relatively long burst over an entire sector.

Buffering the data and matching the data spectrum to the special characteristics of the read/write process decreases the bit-error rate of the read information. Dropouts are detected by reading the information immediately after it has been recorded and comparing the detected and demodulated data with the original information in the buffer. If the comparsion does not match, the sector is invalidated and the information is rewritten on another sector. Essentially all of the errors can be corrected during the recording process. [7]
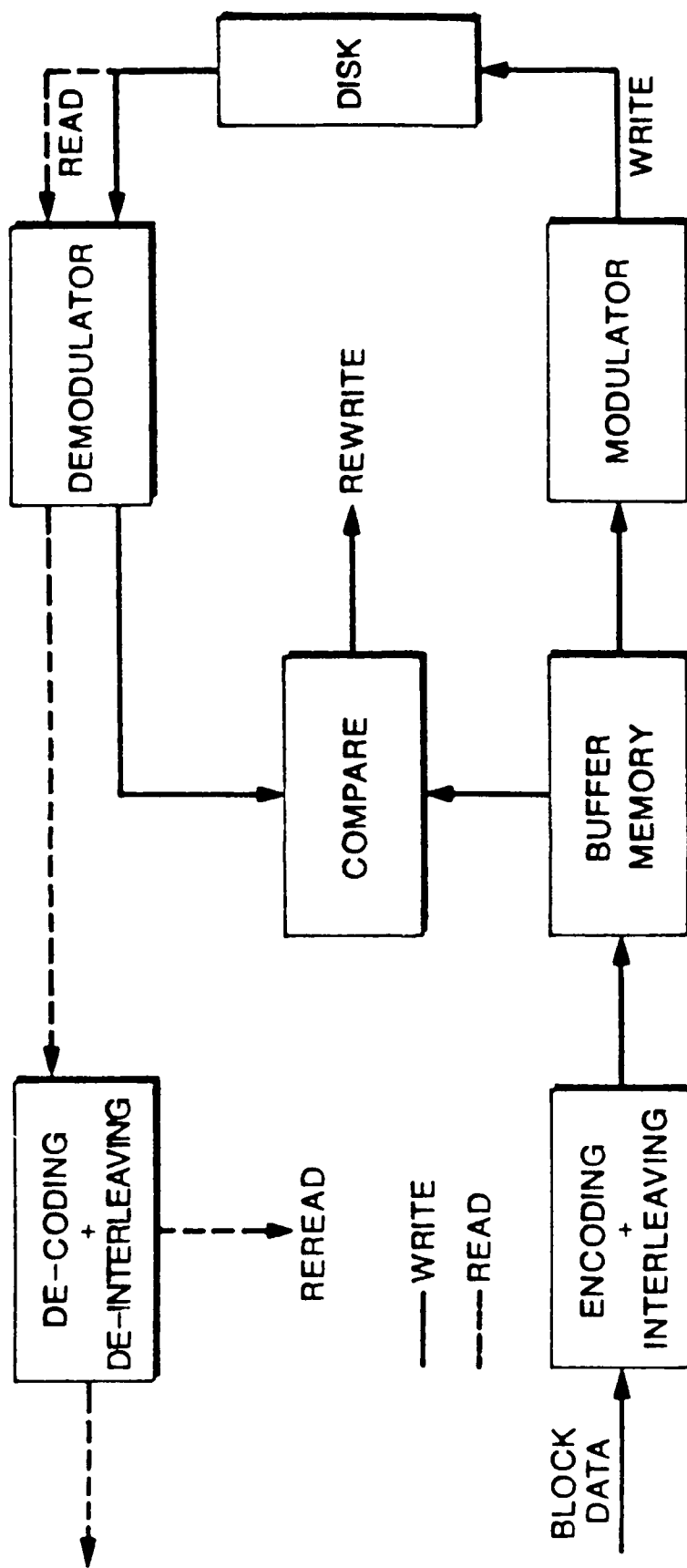
FIGURE TWO. Error Correction System for an Optical Recorder

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4.0 ERASABLE OPTICAL STORAGE SYSTEMS

4.1. It seems clear that the impact of optical storage systems as replacements for magnetic tape or disk storage systems will not be until a reliable method of erasure can be developed and proven. The inability of present systems to provide for erasure and subsequent re-recording of data limits their ability to compete with magnetic systems, where erasure is a requirement. When multiple read/write/erase systems become available, optical storage systems can be expected to replace magnetic storage systems in those applications. Promising research on erasable optical systems is now underway, and some units will be completely available within the next two or three years.[8] This Section will describe the general character of erasable storage systems and indicate some of the problems that must be overcome before they reach a commercial stage of development.

4.2 Three different approaches toward erasing an optical storage system are currently under development- phase-change, magento-optic and erasable light-sensitive dyes. In phase-change technology the recording medium mmust be heated and quenched quickly to force the recording medium from an amorphous to a crystalline state. Reversing the process requires reheating the medium and slow cooling, this process degrades the recording meduim over time, limiting the number of erasure cycles the disk can withstand before they must be replaced.

Phase-change technology was very popular a few years ago, but disk life problems will probably prevent its acceptance, given the existence of a competing technology that does not appear to suffer from that disadvantage. Erasable light-sensitive dye techniques have only recently appeared in the literature, and preliminary indications are that it can be a relatively low cost technology, though dye fading problems appear to limit its usefulness to a few hundred write-erase-write cycles. Magneto-optic systems

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promise an essentially unlimited disk lifetime,

and the remainder of this section will describe its operating principles, promise, and capabilities.

4.3 Magneto-optic storage systems use a laser beam to write and read data from a specially prepared metal surface - usually a thin amorphous film of some rare-earth transition metal deposited on a glass or plastic substrate.[9,10,11,12,13] Erasable systems utilize the laser's heat to change the magnetic properties of the metallic disk, not to burn a pit or form a blister on the recording medium as is done with write once systems. This technique has been found to work effectively with materials that exhibit a coercivity greater than 3000 Oersteds. The disks are magnetized uniformly in one direction during manufacture.

When writing, the laser beam heats a very small portion of the disk surface to its Curie point, the temperature of transition at which the phenomena of ferromagnetism disappear and the substance becomes merely paramagnetic - a temperature that is usually lower than the melting point of the substance. The Curie point ranges between 130° and 150° C. When the magnetic material cools below its Curie point, its flux lines will assume the direction of the flux lines of an applied external field that opposes the direction of the field in the premagnetized disk. A magnetized domain thus reversed represents a binary digit "one" in digital recording applications, while an unreversed domain represents a binary "zero". The basic configuration associated with this effort is shown in Figure Three.

4.4 Laser power required to affect the change in magnetism described above is approximately ten milliwatts. To read the bit domains, the same laser, operating at approximately 1 milliwatt, bounces its beam off the surface of the disk through an objective lens and a photodetector. In some systems the disk is transparent, and the

FOCUSSED
LASER BEAM

MAGNETIC
FIELD LINES

MAGNETIC FILM

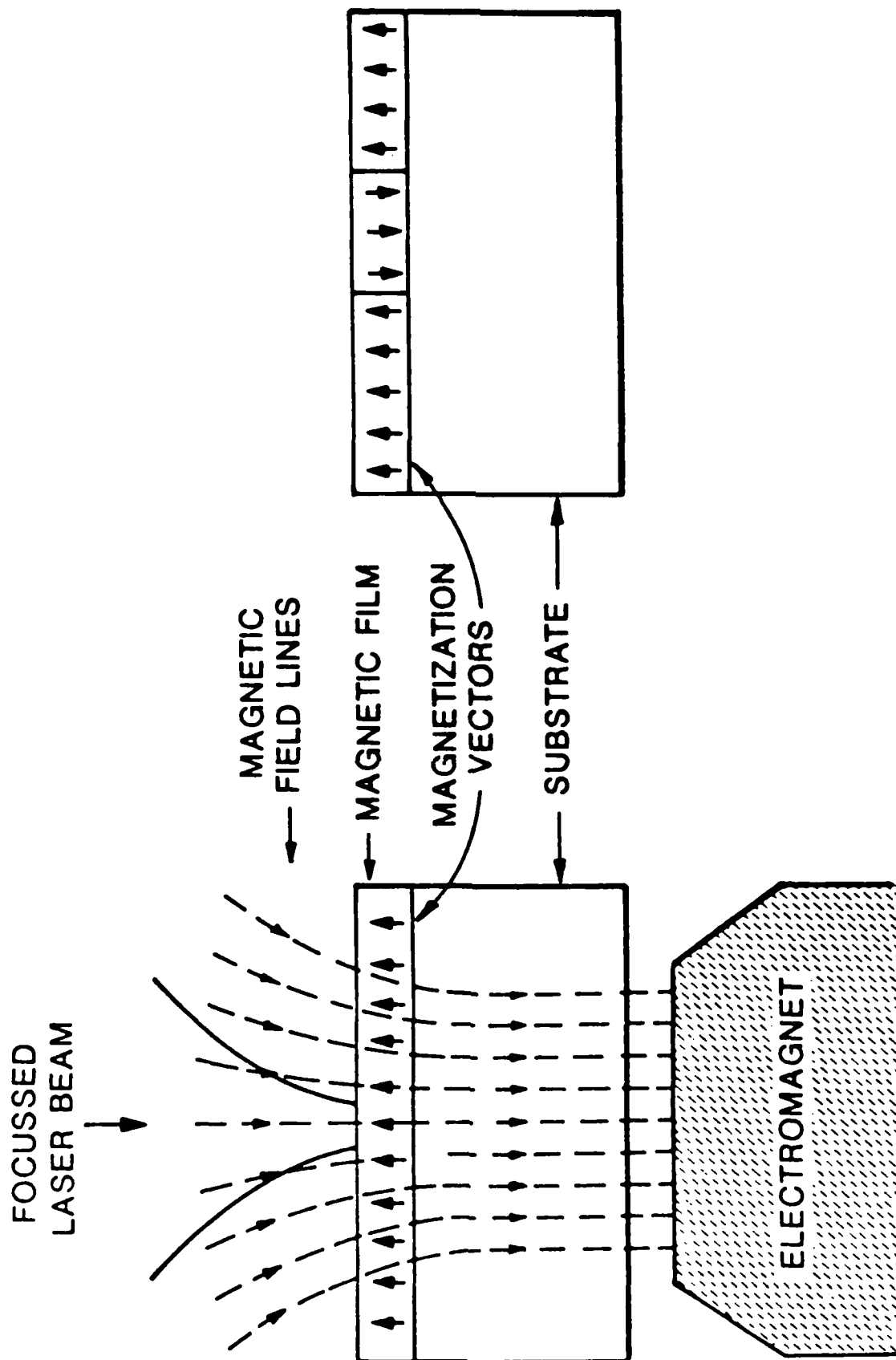MAGNETIZATION
VECTORS

SUBSTRATE

ELECTROMAGNET

FIGURE THREE.   Illustration of the Basic Write System in a Magneto-optic System
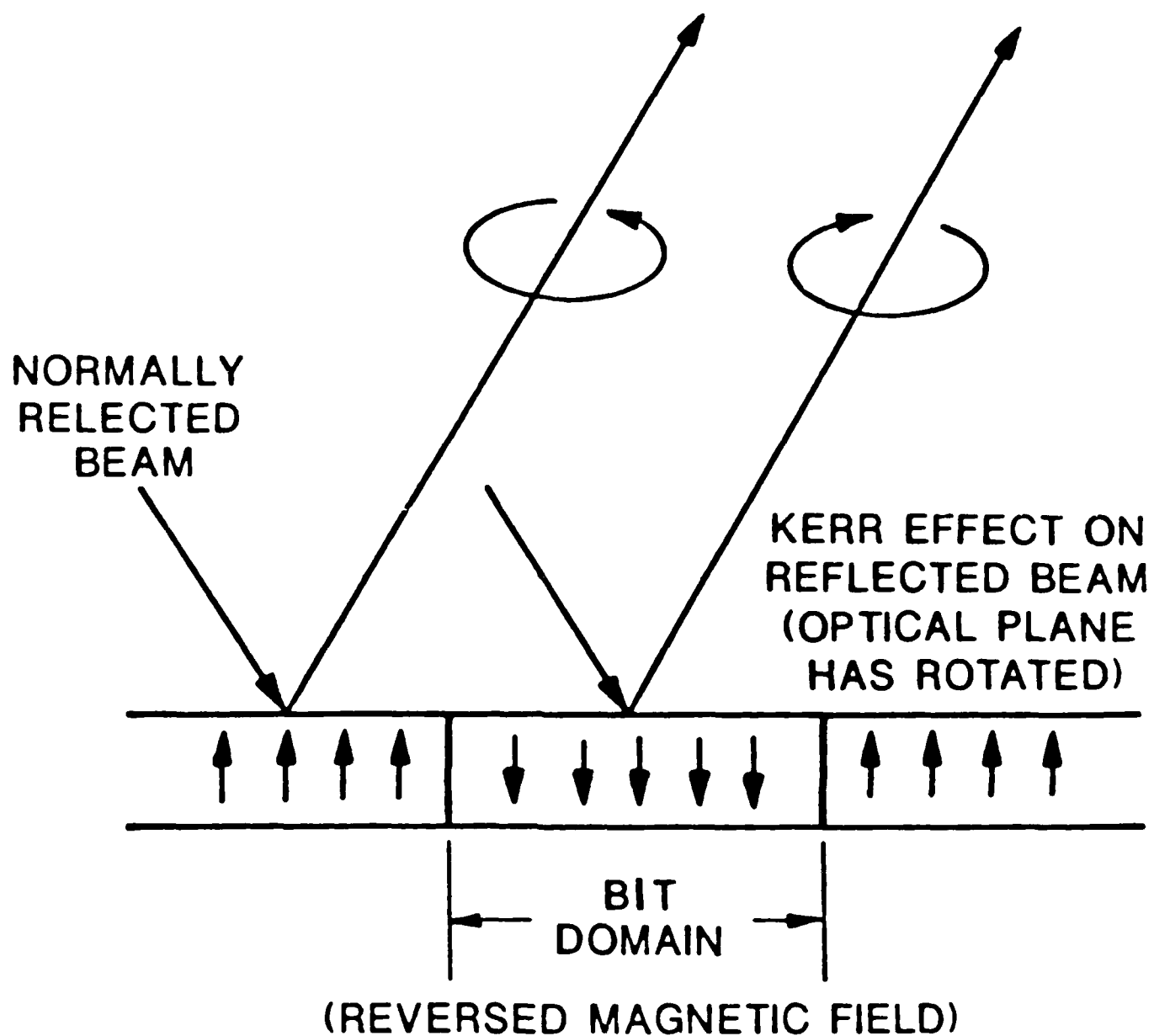
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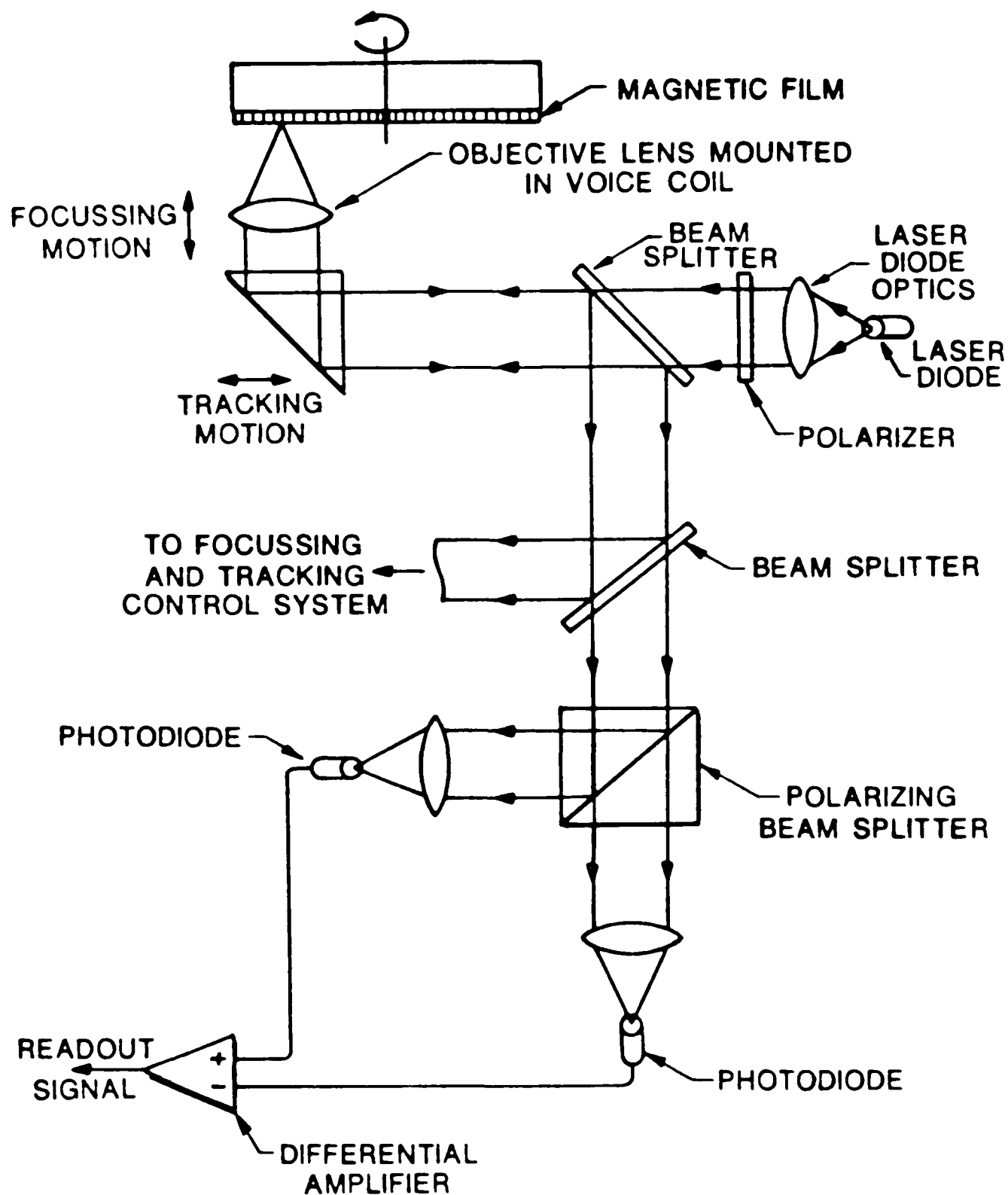Figure Four.   General Character of the Kerr Effect

FIGURE FIVE. Optics used in Kerr Effect Magneto-optic Systems

It has been found that the reversal of the flux lines caused by the write pulse causes the plane of polarization of the reflected (or transmitted) light to rotate slightly, and that the reversed bit domains appear as a series of black spots on a light background with the objective lens has an appropriate polarizing filter. [15]

This phenomena is known as the Kerr effect when reflected light is used, and the Faraday effect when the light beam passes through a transparent medium. The Kerr effect is illustrated in Figure Four, and a digram information based on the Kerr effect is shown in Figure Five. [15]

The interrogating laser beam is first collimated and polarized, and, after passing through the beam splitter, is focused on the magnetic layer of the disk. The effect of the beam splitter on the incident beam is relatively unimportant here, but the incident beam must pass through the splitter if the reflected beam is to be separated out for analysis. The beam splitter thus separates the reflected beam and directs it toward the detection arm of the system. Here the polarizing beam splitter divides the energy of the beam between the two photodetectors according to the logic state at that point. Therefore, as the disk rotates under the beam the output of the differential amplifier reproduces the pattern of magnetization. [15]

Advocates of Kerr effect systems point to the fact that such systems can make use of both sides of a disk, and Faraday system developers [8] believe such systems will ultimately prove to be less expensive than competing Kerr effect systems, primarily because of the in-line orientation of the laser and polarized objective lens. Figure Six describes a system based on the Faraday effect. [18]

4.5 Erasure can be accomplished by repeating the above process with field reversed. [16] Overwriting involves an erasure, then delaying one revolution (to allow the spot to cool) before writing again. Fast erasure is possible because the time required for cooling is less than 1 microsecond.
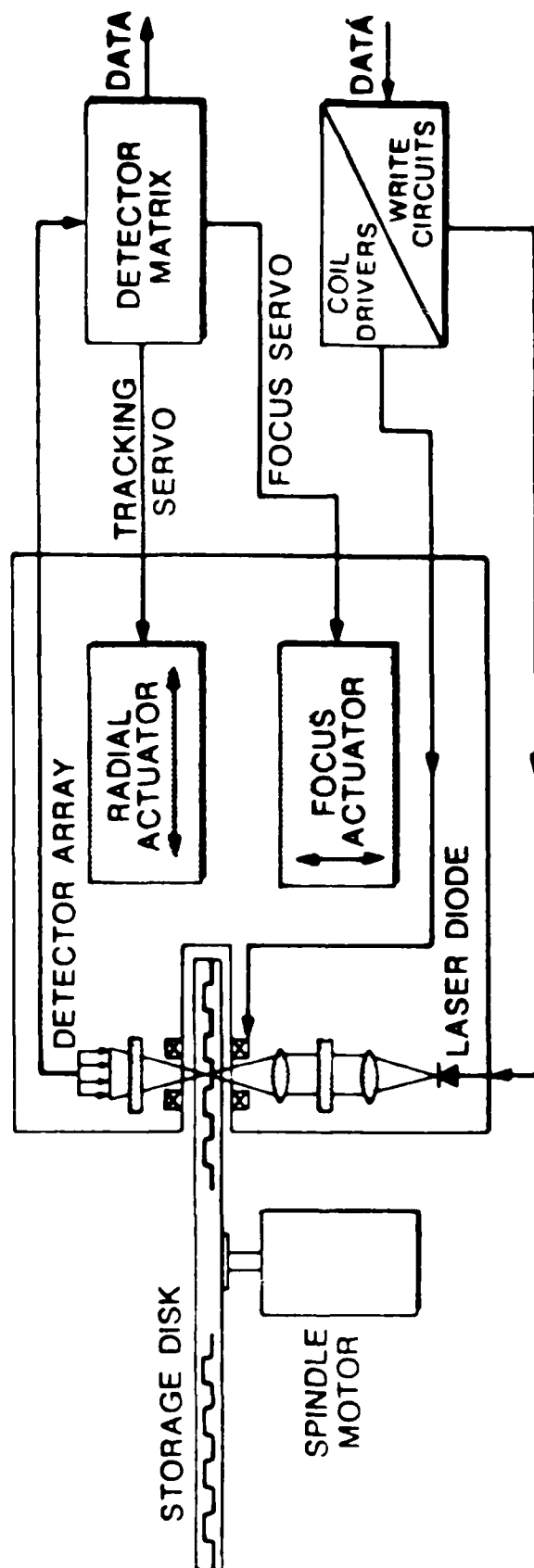
FIGURE SIX. Schematic of a Faraday Effect Magneto-optic System

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4.6   The polarization angle caused by the Kerr (or Faraday) effect is very small-less than one degree. The signal generated by these effects is accomplished by noise from a variety of sources, including shot noise due to a quantum nature of photodetection, thermal noise in the electronic circuitry, and noise due to surface roughness and discontinuities in the magnetic media. [14] At present, the signal/noise performance of erasable optical system does not approach that of write once systems though promising research is expected to narrow this gap within a relatively short time. [17]

5.0 SMALL COMPUTER SYSTEMS INTERFACE

5.1   Most optical disk system manufacturers have adopted the Small Computer Systems Interface (SCSI) as a standard interface for coupling to a computer. [18] The SCSI standard was developed by an American National Standards committee that attempted to set constraints for an interface that was capable of interconnecting multiple computers and their peripherals. Device independance allows new peripherals, such as optical disk systems, to be integrated easily into an existing computer system through an SCSI port without major hardware or software development problems. [18]

5.2   SCSI is an eight-bit, bi-directional, parallel interface. It provides most computers with device independence within a class of devices by using a standard 50-pin bus and a general set of high-level commands. [18] Hardware and software installations of additional devices are greatly simplified and SCSI interfaces are available for most popular mini and microcomputers that are backplane based or have expansion slots.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Storage systems utilizing laser read/write technology are commercially available,

and they are rapidly replacing magnetic tape and other storage media in a wide variety of applications. An optical disk "jukebox" mass storage system that can provide access to any data in a store of 1250 gigabytes within six seconds has been developed by RCA Corporation, engineering models of that system are planned for NASA Marshall Space Flight Center and the Air Force Rome Air Development Center. [19]

Write once optical technology, though new, is commercially available from a variety of sources. For many applications, such as telemetry recording, the fact that erasure is not possible with such systems is not a significant disadvantage. Many who are intrigued by write once technology hesitate to invest in it because of the promise offered by the systems that can provide multiple write/erase/write cycles. Such hesitation can be costly however, and those who wish to be at the leading edge of this new technology would do well to acquire write once systems and evaluate their characteristics. Experience gained by taking such an action is certain to translate directly to the write/erase/write systems as they become available - given their essential compatibility through an SCSI interface.

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APPENDIX B

The following pages are reproductions of vendor data sheets for
the components proposed in the evaluation.

Optotech SCSI Controller

Features

- Selectable Interleave through 1:1.
- Multi-track buffer.
- Static Error Handling on formatting.
- Dynamic Error Handling at runtime.
- Supports one to four disk drives.
- Alternate sectors divided into 9 bands for fast access.

- ECC correction of up to 24 bytes of bad data per sector (The most powerful ECC in industry).
- User formatting capability.
- LSI implementation for low power draw.
- Disks written using SCSI or PC Controllers are totally interchangeable.

Optotech SCSI Controller Block Diagram
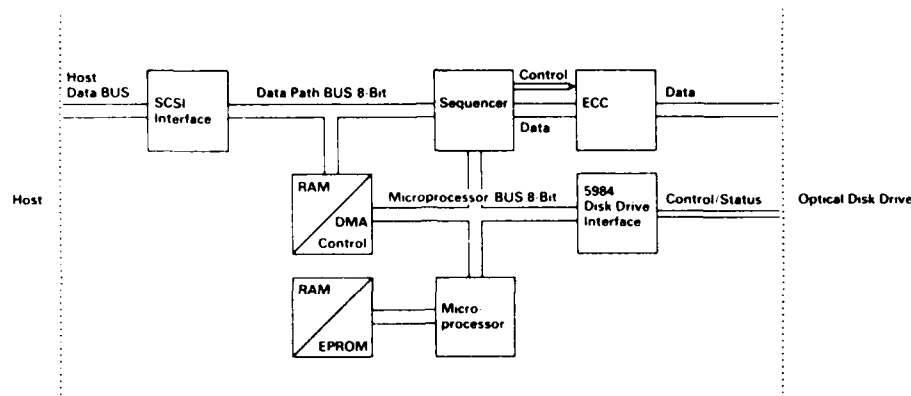
Optotech SCSI Controller Command Set

OP Code	Command Name	OP Code	Command Name
00	Test Unit Ready	39	Compare
01	Rezero Unit	0A	Write
03	Request Sense	0B	Seek
04	Format Unit	1A	Mode Sense
07	Reassign Blocks	1B	Start/Stop Unit
08	Read	1C	Receive Diagnostic Results
12	Inquiry	1D	Send Diagnostic
15	Mode Select	1E	Prevent/Allow Medium Removal
16	Reserve Unit	2A	Write Extended
17	Release Unit	2B	Seek Extended
18	Copy	2E	Write Verify
25	Read Capacity	2F	Verify
28	Read Extended	3A	Copy and Verify (Vendor Unique)
30	Search Data High	3B	Write Data Buffer
31	Search Data Equal	3C	Read Data Buffer
32	Search Data Low	CA	Write Post Field
33	Set Limits	C8	Read Post Field
37	Read Defect Data		

Requirements

- **Power** 5 Watts at 5 Vdc. 1 Amp (Max)
- **Voltage**. 5 Vdc 5°o
- **Size**. Controller Board is standard 5 75 by 8 0

Optotech PC Controller

Features

- Selectable DMA or Program I/O data transfer.
- Automatic seek and verification.
- Automatic ECC is the most powerful in the industry
- Disks written using PC or SCSI controllers are totally interchangeable.
- Static Error Handling mapped at disk format time.
- Dynamic Error Handling at runtime.

- Alternate Sectors are divided into 9 bands for fast access.
- One to four disk drives are supported.
- Single PC slot (piggybacked boardset).
- Low power requirements (15 Watts).
- Two optional commands available to Read/Write Post Field for updating Write-Once data files.
- 4:1 Interleave.

Optotech PC Controller Block Diagram
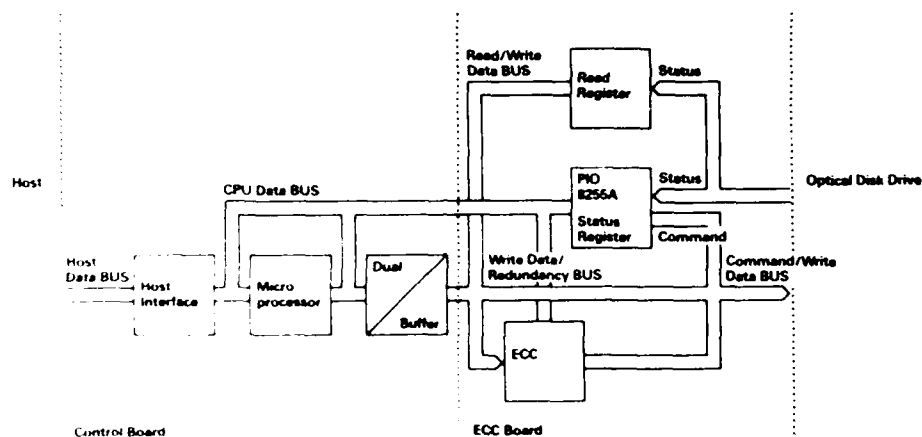
Command Set

00	Test Unit Ready	1C	Receive Diagnostic	Seek, Select, Deselect, Reset, ECC Control, and Read and
01	Rezero Unit		Results	Write Extended are implied in Send/Receive Diagnostic
03	Request Sense	1D	Send Diagnostics	Command
08	Read	1E	Prevent Allow Media	
0A	Write		Removal	All commands are supplied to the PC Controller in a
0B	Seek	3B	Write Data Buffer	fixed length command block, similar to the SCSI interface
		3C	Read Data Buffer	specification. Status results are returned in a similar block.
		CA	Write Post Field	
		C8	Read Post Field	

Requirements

- IBM PC or Hardware Compatible Device
- Power Requirements 15 Watts at ±5 Volts
- Physical Requirements One full-length card slot

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SPECIFICATIONS

Disk Cartridge

Model		OC301-1	OC301-2
	Disk Capacity	1.310 MB	2.620 MB
Storage Capacity (Formatted)	Track Capacity	31 7 KB/track	
	Sector Capacity	512 B/sector	
Recording Density		19.500 bpi	
Track Density		16.000 tpi	
Number of Data Tracks		41.300	
Number of Track Sectors (alternate)		62 (2)	

Formatter Controller

Model	OF301S-1/2
Interface	ANSI X3T9 2 (SCSI)
Data Transfer Rate (max)	1 5 MB sec
Buffer Size	Equivalent to two tracks

Model	OF301G-1
Interface	IEEE488–1978(GP-IB)
Data Transfer Rate(max)	1 MB/sec
Buffer Size	Equivalent to two tracks

Disk Drive

Model		OD301A-1
Data Transfer Rate (max)		440 KB/sec
Access Time	Average Seek Time	200 ms
	Average Latency	50 ms
Rotational Speed		600 rpm

Library Unit

Model		OL301S-11/21	OL301S-12/22
Total Capacity (Formatted)	Total Capacity	42.000 MB	83.900 MB
	Number of Cartridges	16	32
Average Access Time	Mount	8 sec	9 sec
	Demount	7 sec	7 5 sec

Note		
	OF301S-1	Single End Interface
	OL301S-1X	
	OF301S-2	Differential Interface
	OL301S-2X	

Physical Characteristics

Model		OF301S-1/2	OD301A-1	OL301S-11/21	OL301S-12/22	OD301A-L1
Power Requirements	AC	—	--	100/115/120 V or 200/208/220/230/240 V		
		—	—	50/60Hz Single Phase/3 Wires		
	DC	+24 · 10 0 2A	+24V · 10 6 A (start-up/peak) 3 A (operating)	Library Unit converts AC power to DC power		
		+5V · 5 · 10 A	+5V · 5 · 7A			
		-12V · 5 · 2 A	12V · 5 · 3 5A			
Power Consumption		—	—	1 2 KVA (2 1 KVA*)		0 2 KVA
Heat Dissipation		—	—	1,000 Kcal/h (1,800 Kcal/h*)		170 Kcal/h
Dimensions	Width	80 mm (3 15 in)	380 mm (14 96 in)	1,250 mm (49 21 in)	1,250 mm (49 21 in)	380 mm (14 96 in)
	Depth	290 mm (11 42 in)	650 mm (25 59 in)	700 mm (27 56 in)	700 mm (27 56 in)	650 mm (25 59 in)
	Height	310 mm (12 20 in)	160 mm (6 30 in)	1,250 mm (49 21 in)	1 524 mm (60 00 in)	160 mm (6 30 in)
Weight (Approximate)		6 kg (13 lbs)	25 kg (55 lbs)	380 kg (838 lbs)	420 kg (986 lbs)	30 kg (66 lbs)
Environmental Conditions	Temperature	Operating	5 45 C			
		Non-operating	10 50 C			
	Relative Humidity	Operating	8 80			
		Non-operating	8 90			
	Vibration	Operating	0 25G or less			
		Non-operating	1G or less			
	Shock	Operating	2G or less			
		Non-operating	5G or less			

The above specifications are subject to change without prior notice   *Only when the cartridge is being loaded or unloaded

Optical Disk Drive 5984

Benefits

- High capacity, low cost per stored bit in standard 5¼" form factor make the 5984 the most cost-effective storage solution for on- and off-line applications.

- Removable disk cartridge protects media and allows data to be interchanged across drives. Recorded data has a projected life of 10 years or more, making it ideal for archival purposes. No backup is required.

- Disks are updatable, thus supporting applications where audit trails are required.

- Pre-grooved media provides faster access and up to twice the storage capacity of flat media.

- Designed-in product reliability is highest in the industry. Proprietary Direct-Read-During-Write techniques for data verification ensure system error rates less than 1 in 10¹². MTBF is 20,000 hours.

Markets and Applications

- Electronic file cabinets in small business and office automation systems
- Low cost archival systems
- Local and distributed data bases
- Medical, pharmaceutical and legal records
- Financial records with audit trails
- Software distribution and updating
- Electronic publishing
- Military/space mission control and logging
- Image storage and retrieval systems
- Data logging
- On-line mass storage with integral backup

Drive Specifications

Performance

Data Transfer Rate	2.2 Mbits/sec.
Rotational Speed	1200 rpm
Seek Time	475 msec. max
	195 msec. average
	1.5 msec. track-to-track
Average Latency	25 msec.
Access Time	525 msec. max
	220 msec. average
Linear Velocity (innermost radius)	3.77 mm/msec.
Linear Velocity (outermost radius)	7.54 mm/msec
Positioning (Seek) Error Rate	10⁻⁷
Corrected Read BER	10⁻¹²
MTTR	15 minutes
Preventive Maintenance	None
End User Maintenance	None
Design Life	5 years

Physical and Environmental

External Dimensions (W x H x D)	146 x 85.1 x 203 mm.
	5.75 x 3.27 x 8 inches
Weight	5.2 lb.
	2.35 kg.
Power Requirements	+ 5 Volts @ 0.5 Amps
	+ 12 Volts @ 0.75 Amps
Power Consumption	12 Watts average
FCC Rating	Class B
Temperature (operating)	0°C to 40°C
Relative Humidity (operating)	90%, non-condensing
Altitude	1200 ft. to 12,000 ft.

Media Specifications

Performance

Capacity/Side (raw)	244.3 Mbytes
Capacity/Side (user)	202.4 Mbytes
Data Surfaces	2
Tracks/Side	18,826
Track Pitch	1.6 μm
Bit Spacing	1.71 μm
Sectors/Track	21
Sector Size (raw)	644 bytes
Sector Size (user)	512 bytes
Overhead (Header, ECC)	26%
Projected Storage Life	10 years

Physical and Environmental

Disk Diameter	5¼ inches
	120 or 130 mm
Outermost Track Radius (130 mm disk)	60 mm
Innermost Track Radius (130 mm disk)	30 mm
Weight	53 lb
	24 kg
Storage Temperature	10 C to 50 C
Storage Humidity	95% non condensing

END
7-87
DTIC